Structural investigation of Si/3C-SiC/Si(001) heterostructure by transmission electron microscopy

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1. INTRODUCTION

Silicon carbide (SiC) has attracted attention for decades due to the prominent mechanical and electrical properties that this material has to offer. The cubic phase (3C-SiC) shows an advantage compared to other polytypes which is the ability to be hetero-epitaxially grown on low-cost silicon (Si) substrates [1]. In the last decades, 3C-SiC has been drawing attention for microsensing applications for microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) devices [2,3]. Our group has shown that the heteroepitaxy of a Si layer on top of the 3C-SiC/Si heterostructure provides additional interest to the 3C-SiC in MEMS/NEMS devices due to the original applications that can be considered [4,5]. However, the 3C-SiC and the Si substrate show a large lattice mismatch (20%), a difference in thermal expansion coefficient (8%) and different crystallographic structures. These differences induce the presence of stacking faults, micro-twins and antiphase domains (APDs) in the 3C-SiC layer. The APDs are commonly observed when a polar material, as 3C-SiC, is grown on non-polar material as Si. Furthermore, the subsequent epitaxy of a Si layer on top of the 3C-SiC layer is expected to show defects related to the growth itself, in addition to defects which are a direct consequence of the presence of some type of defects on the 3C-SiC surface.

In order to have an insight on the optimal Si layer crystal quality that can be reached, we need to clearly identify the defects generated in the Si layer during the growth and those related to the presence of defects on the 3C-SiC surface. Therefore, transmission electron microscopy (TEM) investigation was carried out on the Si/3C-SiC/Si heterostructure.

2. RESULTS

2.1 Experimental details

The Si/3C-SiC were grown by chemical vapor deposition in a hot wall reactor. Detailed information on the growth conditions are given elsewhere [6]. The structural properties of the Si films were assessed by cross section and plan-view TEM using a JEOL-JEM 2010 FEG, operating at 200 kV.

2.2 Results

In this work, we discuss the impact of the 3C-SiC(001) quality on the subsequent Si film. We prove, using electron diffraction patterns, that the 3C-SiC is hetero-epitaxially grown along the [001] direction on Si(001) substrate while the Si epilayer is grown along the <110> direction. The diffraction patterns of the Si film show the presence of different Si grains rotated by 90º around the growth direction. We were able to prove that the grain formations is directly linked to the presence of antiphase domains on the 3C-SiC surface [7].

Plan-view TEM images confirm the previous results showing the presence of two domains rotated by 90º around the growth direction, as depicted in Fig. 1a. Furthermore, a thorough study of the Si epilayer reveals the presence of hexagonal Si structure. This structure is observed for small areas in a Si domain (denoted C2) enclosed within a larger domain (denoted C1), C1 and C2 domains differing from each other by a 90° rotation around the growth direction.

3. CONCLUSION

Finally, based on our results, we prove that the Si grains rotated by 90º around the growth direction are strictly linked to the presence of APD on the 3C-SiC surface. We thereby stress on the necessity to improve the 3C-SiC film quality, prior to the Si film growth.

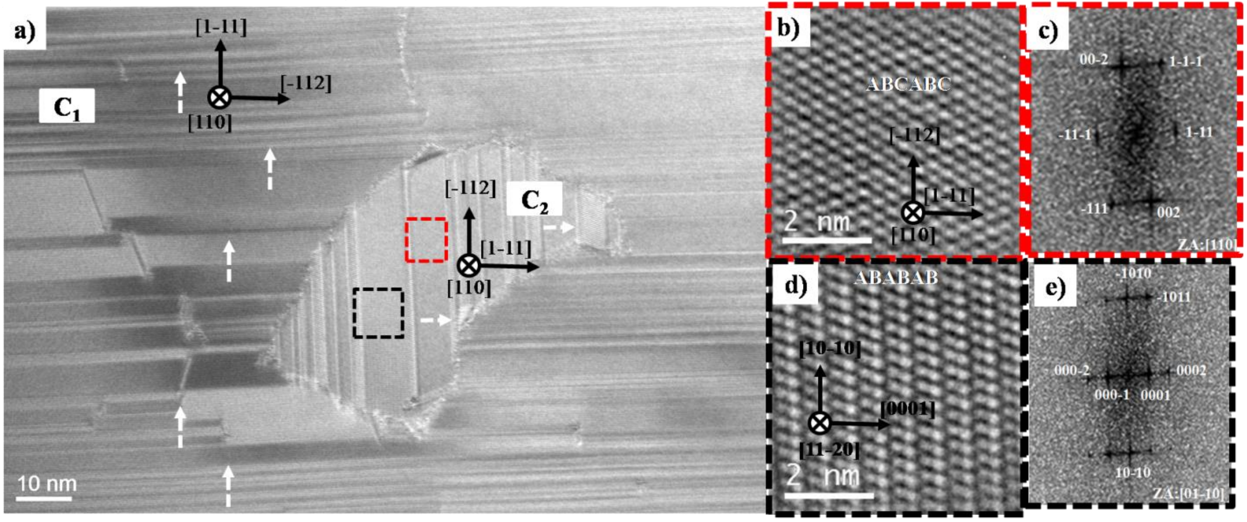

Figure 1. a) High resolution plan-view TEM image of the silicon layer showing two domains rotated by 90° (C_1/and C_2), the dashed white arrows indicate twins in the Si layer. b) higher magnification of the region indicated by red dashed square showing typical cubic structure, c) the corresponding FFT, d) higher magnification of the region indicated by black dashed square showing hexagonal structure, e) the corresponding FFT.

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